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ABSTRACT

Many Australian university students who are preparing to teach elementary mathematics lack confidence in their own knowledge, understanding and use of mathematics. Such a lack of confidence appears soundly-based. In this paper, a compulsory mathematics course for elementary teachers in training is described, the aims of which are to build the confidence and competence of such students. An argument is presented for the course being built around cooperative problem solving, and experiences of teaching the course in such a way for the past three years are given. Information is given on course content, pedagogy and assessment. (Author)

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A Compulsory Mathematics Unit for Elementary Preservice Teachers: Content, Pedagogy and Assessment

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Introduction

The statement that many preservice students studying to become primary teachers lack confidence in their understanding of mathematics is not new to readers of this paper. Given the difficulties that these students have with mathematics and the misconceptions that are quickly revealed in our courses, this lack of confidence appears well-justified. As they recount their school mathematics experiences, they often regard this time very negatively, consider mathematics to be "rules without reasons", and regard themselves as mathematical failures.

The challenge for those of us who work with such university students is therefore two-fold: to boost their confidence and competence in the subject, and to present mathematics as a key to solving worthwhile and meaningful problems.

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One approach that we believe is destined to fail is to provide "more of the same"—worked examples on the board, followed by the chance to do 30 almost identical exercises, before moving on to the next worked example. Many students have had years of this approach, and long-term retention and understanding seems limited.

In accord with the concerns with competence in discipline knowledge highlighted in the Australian*Discipline Review of Teacher Education in Mathematics and Science* (the "Speedy Report"; Department of Employment, Education and Training, 1989), in 1992 Australian Catholic University introduced a compulsory mathematics unit for all primary teachers in training. This unit is taught across all eight campuses of the University. Satisfactory performance in this unit is an essential hurdle in the Bachelor of Arts/Bachelor Teaching Course. This article discusses the content and approach of this unit as taught over the period 1994-1996 in Melbourne campuses of Australian Catholic University.

Building Confidence

I am increasingly convinced that one of the keys to building confidence is to develop an atmosphere of *valuing* a variety of methods in solving problems and *building upon* these. Whether or not previous teachers intended it, students come to a university assuming that there is *one* way to solve a given problem—the teacher's way or the textbook's way. If this is true, and if that method is not understood, then it follows that there is little chance of success in the subject.

On the other hand, if students' own methods of solution make sense, are reasonably efficient, and work in a variety of situations, then we encouraged students to "go ahead and use them". This can be highly empowering for many students. The opportunity to share their thinking and to learn from others' methods is likely to lead to progress to more efficient methods, while still providing students with the important element of choice. The comment that "for the first time ever, I am being told my methods are okay" is common, and the resulting boost to confidence is most evident.

Essential Content

Over a twelve-week semester (three hours per week), it is unrealistic to expect that all the "big ideas" of mathematics can be addressed, and so tough decisions need to be made about appropriate content. Some universities decide that if students work through absolutely new content (vector spaces, say), they will see the beauty of mathematics and gain a new appreciation of the subject. There is some substance to this argument, but when students are initially struggling with ordering decimals or the differences between a rhombus and a square, other content priorities are imperative.

I have tended to build the unit around the big ideas of school mathematics, in an attempt to develop a *connected* understanding of these, in many cases, for the first time. I therefore take content from number, geometry, measurement, algebra, and probability and statistics. Obviously, the content depth cannot be great, but it does provide some basis for further growth during the mathematics education units in subsequent years.

A Problem Solving Approach

> In teaching *via* problem solving, problems are valued not only as a purpose for learning mathematics but also as a means of doing so. The teaching of a mathematical topic begins with a problem solution that embodies key aspects of the topic, and mathematical techniques are developed as reasonable responses to reasonable problems. (Schroeder and Lester, 1989, p. 33)

The whole unit is built around students working cooperatively in solving problems together. For each topic, ten to twenty problems are given, and these are worked through in small groups around tables, with regular whole-class discussion about various methods of solution. We try to encourage an atmosphere of conjecturing, arguing, clarifying and

justifying. The three hour unit is made up of a one-hour lecture followed by two-hour tutorials. The use of lectures isn't particularly well suited to the style of the course, but having over 100 students taking the unit, the university is not prepared to allow the course to be totally taken in groups of 25 or so. The unit outline is given in *Appendix A*.

The mathematics problems used in the unit are more complex than many of the students are used to, and we try to provide many that draw on a range of mathematical topics within the one problem. The problems are also chosen to confront many of the students' mathematical misconceptions in a meaningful context.

We make considerable use of problems and contexts from newspaper articles and current events, so that students start to see that part of the power of mathematics lies in its ability to help make sense of the world, to evaluate arguments (political ones, for example), and to answer important questions.

An example of one problem which we present concerns a (true) story of a man in Devenport who spent two and a bit years of his spare time writing all of the numbers from 1 to 1,000,000. This article was reproduced in Clarke (1994). Using the newspaper article about this man Mike as a stimulus, we encourage students to investigate the figures that are given in the article for accuracy. For example, it is claimed that Mike used 5,878,936 digits in all, and students are challenged to check this (incorrect) figure. Similarly, they are asked to test the claim that all the digits if written one after the other would stretch 176.36 kilometres. In the course of working on this one task, students are using several arithmetic operations, number patterns, length and time measurement, and estimation.

A second example involves students investigating combinations and consequently probabilities in a petrol station promotion. During last year, a particular petrol distributor offered a "scratch and win" type promotion, where purchasers scratched three of seven squares on a card, following their petrol purchase. If they correctly select the three matching squares (and there is always one matching triple), they win the cash prize that has been revealed. Students have to calculate the probability (given various assumptions) that

they will select the correct three by chance. They can then discuss this 1 in 35 chance given that the most common prize was $2, and that the petrol prices may not necessarily have been the cheapest available.

We carefully choose the first set of problems in the unit so that they lend themselves to a variety of different methods of solution, thus providing the chance to value the range of methods that students suggest. In each set of problems, students have some choice of which ones they try.

Students see, for example, that trial and error/iterative methods are most powerful in many situations. We still get the question "but which is the *right* way?", but this question is asked less and less as the semester proceeds.

Because this method of teaching is so different from the prior experience of many students, we take the chance to emphasise that many mathematicians work in just this way, and tell them about the work of the Mathematics-in-Industry Study Group.

In this way, we are *teaching via problem solving* rather than *teaching for problem solving*. The latter, more traditional approach assumes that all we need to do is to teach skills and students will then go away with a "mathematical toolbox", well-prepared for problem solving. We now know that unless we frequently place students in problem solving situations, we can't be confident that the toolbox will be opened at the right time and used in appropriate ways.

Building Understanding

Some readers may be surprised, but the emphasis placed on *understanding* mathematics within the unit is one that is foreign to many students. We recall a comment from one student who, when asked "does your answer make sense?" replied "no, but this is mathematics, and mathematics doesn't usually make sense".

Students probably tire of us saying things like "but *why* can we move the decimal point in that situation but not in this one?", but we emphasise that without a connected

understanding of the subject, short-term repetition of procedures is the best we can hope for, and that meaningful problems need meaningful methods for solution. Hopefully, a consequence of studying the unit is an increased sense of why some of the rules they have been "taught" have developed.

We try to remember at all times that we are preparing the students to be primary teachers, and so we are attempting to model good practice, and give them a sense of what a problem solving classroom might be like as they prepare for mathematics teaching. We are hopeful that the unit increases the chances of them valuing and building upon the thinking of their own students in the future.

Assessment

The unit is formally assessed in three ways. First, students are required to keep a journal of all problem solving attempts, and these are assessed for quality and effort towards the end of the semester.

Second, in pairs, students work on a project entitled "Mathematics Could Be Useful", in which they have to nominate a question of interest to them which mathematics could enable them to answer. They write a detailed report, carefully explaining the question, the process by which they attempted to answer it, the mathematics involved, their findings, and any implications of these. (Information on the project and journal are given in *Appendix B*.)

Third, students sit an exam consisting of a range of problems representative of the kind presented through the unit, some of which are written by the students themselves during revision sessions, a small selection of these being chosen by me for the exam.

The purpose of encouraging the students to develop exam questions is to encourage them to really think about the big mathematical ideas addressed in the unit, and this approach has been an excellent one for revision purposes. This exam is scheduled for three

hours, but the number of questions is chosen so that time is not a particularly important factor.

Some Changes

This is the fourth year (just commencing) in which this unit has been offered in this way. Each year, changes are made. For example, last year algebra was added to the content. This was done for three reasons. First, national and state curriculum documents are encouraging students to move into algebraic thinking much earlier, though not necessarily using abstract symbols. Second, we've found that many students feel "liberated" if they are able to finally make sense of this topic, which was the beginning of the end for many during school studies. Third, many students prefer to use algebraic methods to solve problems, and others are often quite interested to see the close parallels between algebraic methods and their own intutive ones.

Is it Working?

The "proof of the pudding" is probably three years down the track for each student, when students are teaching their own classes, and no such evaluation has yet been undertaken. Student evaluations of the unit have been overwhelmingly positive, with mature-age students particularly reporting that they are now convinced that they can do mathematics, after years of believing that mathematics wasn't for them. Students seem to improve in their confidence and their competence with mathematics, and this can only help their own students in the long run to view mathematics as enjoyable, a key to problem solving, and an important and useful way of helping to make sense of the world.

References

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Appendix A

EMA 100: EXPLORING MATHEMATICS COURSE OUTLINE

Objectives:

On completion of this unit, students are expected to have:

• developed an awareness of their own attitudes to and competence in mathematics and the effect of these on their own learning of mathematics;

• developed personal confidence and competence in the mathematical skills and concepts which are pre-requisites to further mathematics studies.

Teaching Procedures:

Lectures and workshops.

You are required to bring a calculator (basic, with 4 functions), a ruler or Math-o-Mat, [and the Maths Dictionary, if purchased] to all lectures and tutorials.

Assessment Procedures:

Journal of solutions to problems	30%
One major assignment requiring a report of a mathematical investigation (in pairs)	30%
Final 3-hour examination (50% minimum score required)	40%

Additional (non-graded) tasks will be required regularly through the course.

Attendance

There is a minimum attendance requirement of 80% at lectures and tutorials (separately) for satisfactory completion of this unit. In addition, extra work will be provided for students who are absent.

Recommended Text

Fyfield, J. A., & Blane, D. (1993). *The school mathematics dictionary.* Melbourne: Collins Dove.

Week-by-week Course Outline

Week	Lecture & Tutorial Content	Lecture Date	Tutorial Dates
1	Overview of the course content and assessment procedures.What is mathematics? Topic A: Whole Numbers, quick computation, divisibility tests.	Feb 27	Feb 27/28
2	Topic B: Number Patterns & Algebra	March 5	March 5/6
3	Topic C . Fractions & Decimals	March 12	March 12/13
4	Fractions and Decimals ctd.	March 19	March 19/20
5	Topic D: Percentages & Ratio	March 26	March 26/27
6	Topic D ctd.	April 3	April 3/4
	One Week Break for Easter		
7	Topic E: Geometry & Measurement: Spatial visualization, common shapes, similarity.	April 16	Apr 16/17
8	**One Week Break (break for this unit only—made up in Study Week)**		
9	Topic E ctd.: Geometry: (2-D & 3-D); platonic solids, symmetry.	April 30	Apr 30/May 1
10	Topic E ctd.: Measurement (1): Length, area, volume, perimeter, mass.	May 7	May 7/8
11	Topic E ctd.	May 14	May 14/15
12	Topic F: Probability. Statistics: data collection, representation, and interpretation.	May 21	May 21/22
Study Week	Revision	May 28	May 28/29

Appendix B

Exploring Mathematics Project and Journal Task

Project

Working individually or (preferably) in pairs, consider a question or issue that could be answered using mathematics, by appropriate data collection or other relevant processes.

(a) Explain in detail the question or issue of interest.

(b) Describe the process by which you investigated the question, explaining clearly the mathematics you used, assumptions made, sources of data, non-mathematical but important issues, etc.

(c) Summarize your findings.

If in doubt about your choice of topic, you should discuss your proposed assignment with the lecturer. Your report (which should occupy no more than 8 typed pages) will be assessed on the following criteria:

- Clear statement of the question of interest
- Appropriateness of methods used
- How systematic your approach was
- The scope of your work
- The amount of apparent work involved
- Your calculations and/or constructions ("accurate" or "inaccurate")
- Your communication

Problem Solving Journal

Throughout the course, you are required to have an exercise book in which you include solutions to all problems attempted both for homework and during tutorials.

- There will be a minimum number of problems expected each week.

- Lecture notes should be in a separate place from this journal.
- Each week's problem attempts should begin on a new page.
- All entries should be dated.
- The journal should include all working, even if your problem attempts are unsuccessful.

The journal will be collected during the tutorials on May 14/15, assessed, and returned for the following week.